

Near Earth Networks Conference 2003

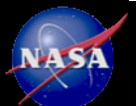
NASA Ground Network

Overview and Interoperability Opportunities

Wallops Flight Facility
June 26 – 27, 2003

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NASA Ground Network Project Manager

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Luis Tsuji
Booz Allen Hamilton Inc.



Agenda

- ▶ **Overview of the Ground Network**
- ▶ Strategic Planning
- ▶ Interoperability Opportunities
- ▶ Discussion



Introduction

▶ **The Ground Network (GN) today**

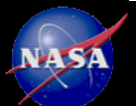
- Diverse network that serves a diverse customer community
- Some current assets are facing cost and maintainability issues
- Budget is driving increased efficiency

▶ **GN planning for the future**

- GN is planning the evolution of its current infrastructure and asset mix
- GN goal is to provide “best value” services
- GN is responding to trends in customer requirements

▶ **Interoperability opportunities to reduce cost and risk**

- GN is interested in increasing interoperability between networks that provide support to U.S. Government missions
- Mutual support and cooperation could lead to greater efficiencies and reduced risk



GN Project overview

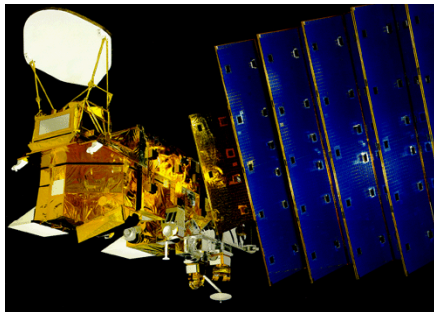
- ▶ Provides ground-based space communications for NASA missions
- ▶ Provides reliable services to meet customer requirements
- ▶ Primary customer is Earth Science Enterprise
- ▶ Also supports many other customers

GN Project Overview	
Enterprise	Earth Science
Program Executive	Mr. Bill Watson
Project Manager	Mr. Roger Clason
Lead Center	Goddard Space Flight Center (GSFC)
Performing Centers	GSFC, Wallops Flight Facility
Program Type	Space Communications Services
Authority	Space Communications MOA approved by NASA Enterprises September 2002



The GN provides services to a diverse customer set

GN Customer Diversity Examples				
Organizations	Phases	Orbits/Trajectories	Frequency	Service Needs
<ul style="list-style-type: none"> ▶ NASA ▶ Other Government ▶ International ▶ Commercial 	<ul style="list-style-type: none"> ▶ Launch ▶ Early Orbit ▶ On-orbit ▶ Disposal 	<ul style="list-style-type: none"> ▶ LEO Polar ▶ LEO low-inclination ▶ GEO ▶ Launch ▶ Sub-orbital 	<ul style="list-style-type: none"> ▶ X-Band ▶ S-Band ▶ L-Band ▶ VHF ▶ UHF ▶ C-band 	<ul style="list-style-type: none"> ▶ Telemetry <ul style="list-style-type: none"> –Housekeeping –Science Data ▶ Commanding ▶ Tracking ▶ Range support



EOS Aqua



Shuttle Launch



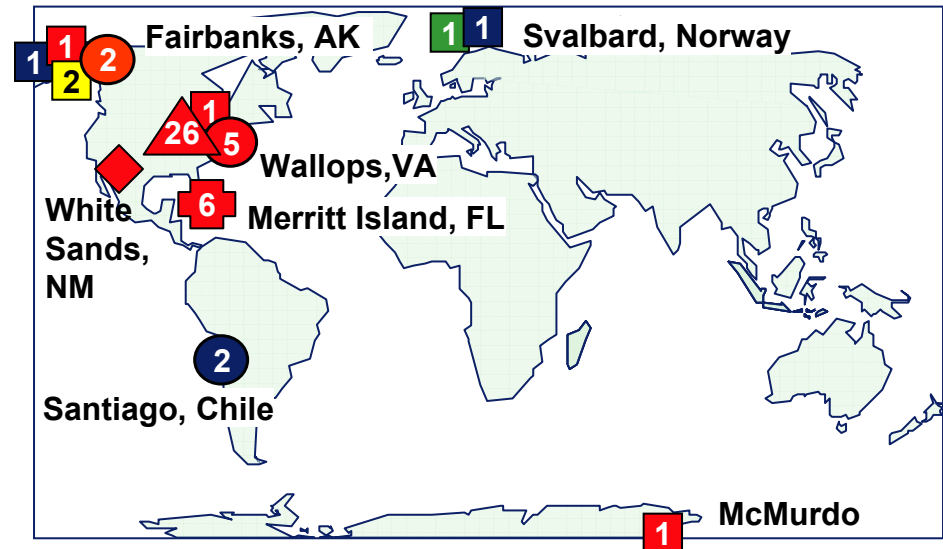
Ultra Long Duration Balloon

Images obtained from: <http://eos-pm.gsfc.nasa.gov/>, <http://www-pao.ksc.nasa.gov/kscpao/captions/100missions/sts-106.htm>, <http://www.wff.nasa.gov/~code820/>

The GN has developed into a complex heterogeneous system

- ▶ 49 ground station antennas;
29 unique antenna systems
- ▶ 6 geographic antenna locations
- ▶ 4 different owner/operator models
- ▶ Numerous IDIQ contracts for additional commercial services as needed
- ▶ Scheduling of all orbital-support antennas performed from one location

GN Antenna Map (Number of Antennas)



Primary Support Category

- Orbital S-Band
- Orbital X-Band
- △ Range
- ⊕ Shuttle
- ◇ Scheduling

Owner/Operator Model

- # NASA/CSOC
- # NASA/university
- # NASA/commercial
- # Commercial



Ground station details

Location	Station	Antennas	Owner	Operator	Downlink	Uplink	Tracking
Alaska	AGS	11m	NASA	CSOC	X, S	S	yes
		8m	NASA	CSOC	S	S	yes
		5m	NASA	CSOC	S	S	no
	ASF	11m	NASA	U. of AK	X	none	no
		10m	NASA	U. of AK	X	none	no
	PF1	11m	DataLynx	DataLynx	X, S	S	yes
Antarctica	MGS	10m	NASA	CSOC	X, S	S	no
Chile	AGO	9m	U. of Chile	U. of Chile	S	S	yes
		12/7m	U. of Chile	U. of Chile	S	S	yes
Florida	MILA/PDL	9m (2)	NASA	CSOC	S	S	yes
		4.3m	NASA	CSOC	S	S	yes
Norway	SGS	11m	NASA	KSAT	X, S	S	yes
	SKS	11m	KSAT	KSAT	X, S	S	yes
Virginia	WGS	11m	NASA	CSOC	X, S	S	yes
		9m	NASA	CSOC	S	S	yes
		8m	NASA	CSOC	S	S	yes
		7.3m	NASA	CSOC	S, L	none	no
		5m	NASA	CSOC	S	S	no



The GN currently faces challenges to cost and performance

► Challenges to GN system performance

- Aging systems increase risk to service performance
- Mission-driven non-standard interfaces and unique hardware limit interoperability
- GN will not meet key mission requirements (e.g., Aqua) in certain ground station contingency situations
- Flat budget limits options for upgrades or new systems

► Challenges to GN system cost

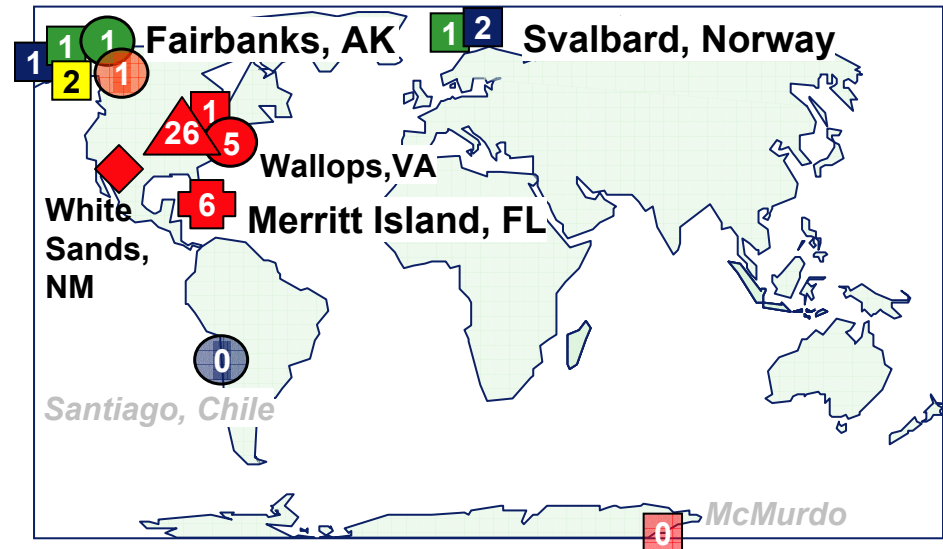
- Maintenance needs for aging and heterogeneous systems
- Manually intensive systems
- Mission unique equipment
- Systems with low utilization



Upcoming changes to GN respond to current challenges

- ▶ Commercialize Alaska ground stations
 - Upgrade/eliminate aging systems
- ▶ Enhance additional Norway antenna
 - EOS contingency support capability
- ▶ Enhance MILA station for orbital support
 - Enable greater GN flexibility
 - Plan replacement of MILA/PDL in '08 to maintain reliability and reduce cost
- ▶ Potentially suspend McMurdo operations in FY '04
- ▶ Consider ending Santiago contract
- ▶ Transition GN operations contract from CSOC to NENS

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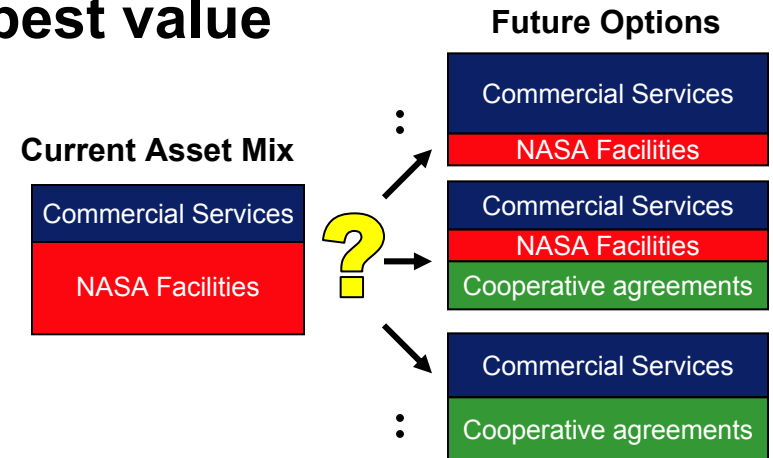
Agenda

- ▶ Overview of the Ground Network
- ▶ **Strategic Planning**
- ▶ Interoperability Opportunities
- ▶ Discussion

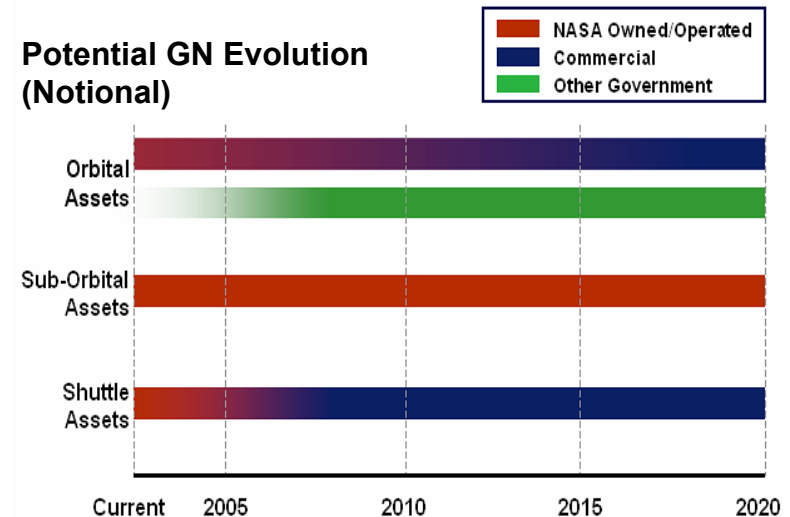


GN evolution options will focus on best value

- ▶ **GN evolution goal is to provide best value**
 - Manage costs to avoid large capitalization
 - Maintain minimum GN civil servant staffing
 - Balance long-term stability and flexibility of ground network capacity
- ▶ **NASA will play active role in managing GN**
 - Manage contracts and budget
 - Insight into contractor processes to enable risk management
- ▶ **General shift from NASA assets to commercial and cooperative**
 - Implementation decisions based on business case merit
 - Performance metrics to assess “future preparation” in addition to past performance

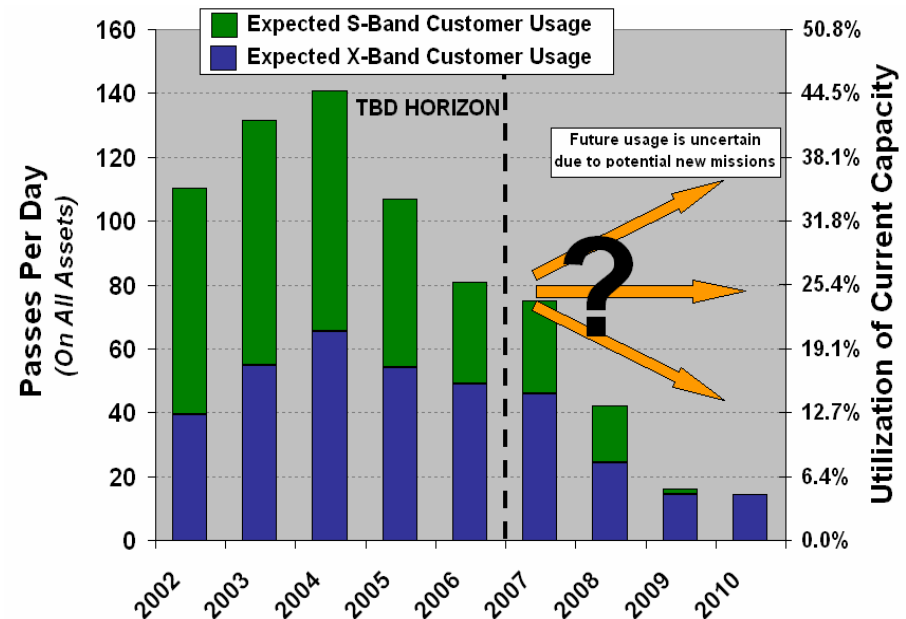


Potential GN Evolution (Notional)



Customer trends motivate and challenge evolution planning

- ▶ **Future orbital customer demand is predicted to change**
 - GN S-band missions “flying out” with few new customers in short term
 - X-band requirement through 2010 for Earth Observing System (EOS)
 - Other mid-term high-rate missions planning to use other networks
- ▶ **GN usage level uncertain beyond ~2007**
 - Far-term mission plans not yet developed
 - Potential for large fluctuations due to possible constellations
- ▶ **GN cannot afford overcapacity**
- ▶ **Must obtain flexibility in capacity**



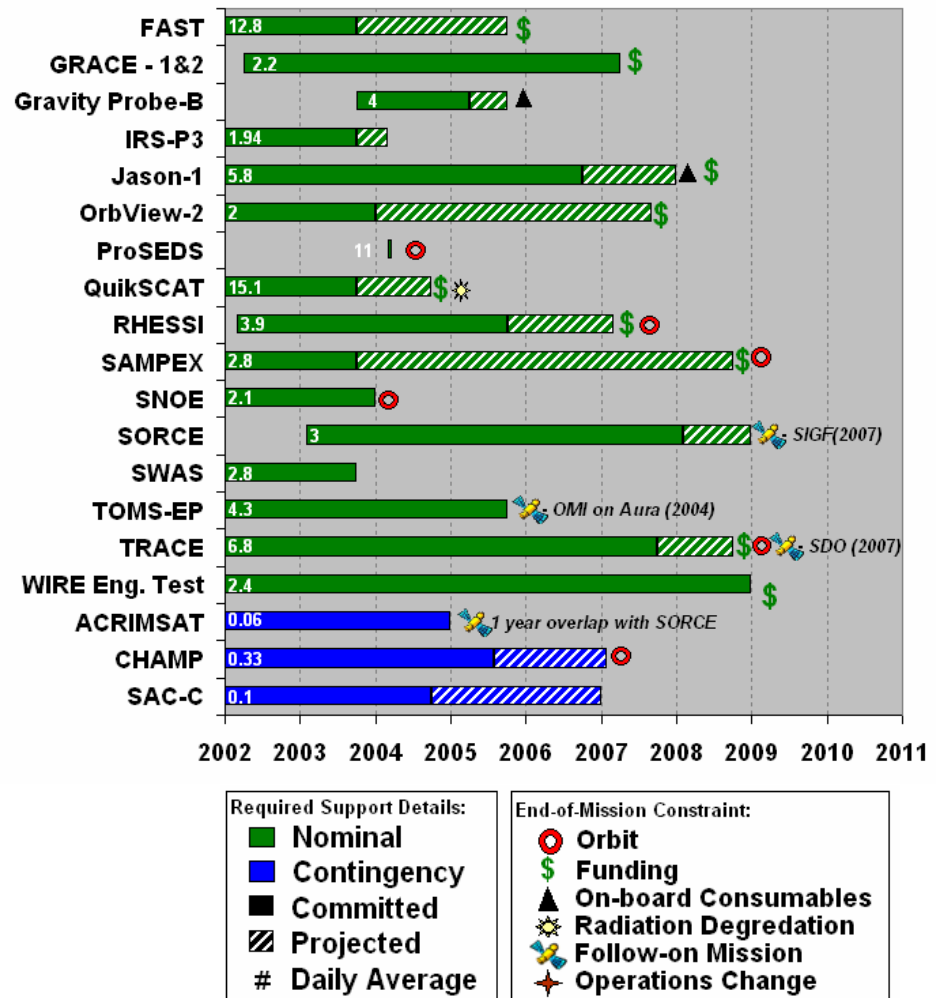
GN Currently has Capacity to Support:

- More than 275 passes/day on NASA owned antennas
- ~40 passes/day minimum on commercial contracts



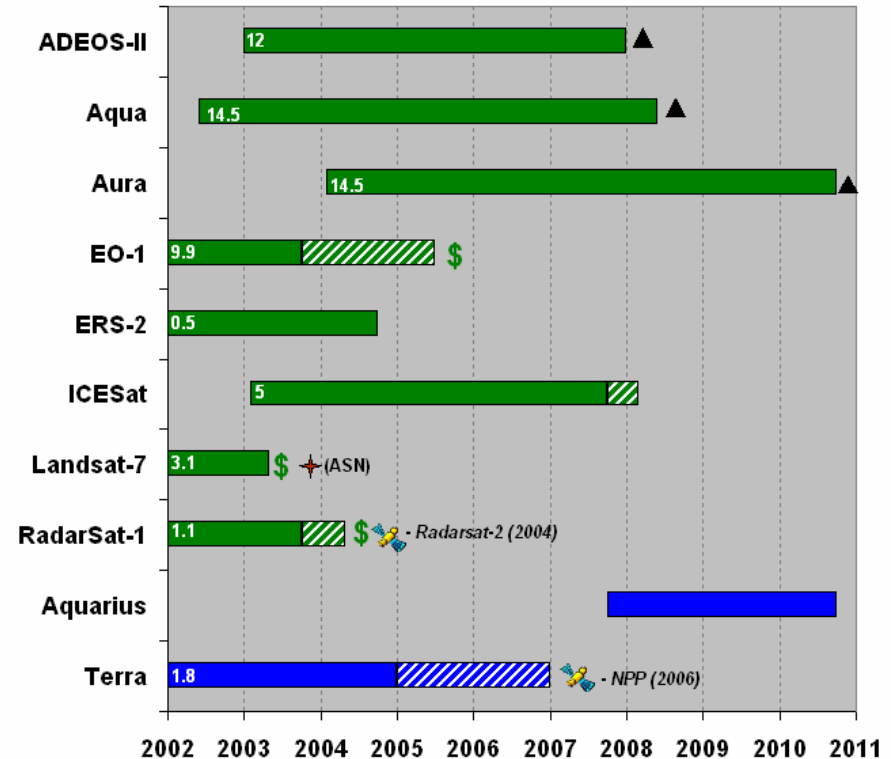
Committed S-Band customer demand declines in short term

- ▶ Significant number of missions ending before 2007
- ▶ No committed GN customers launching after 2004
- ▶ Little potential for yet-to-be-planned missions to launch before 2007
- ▶ Some possible extensions
- ▶ Overall, results in decreasing S-band mission set between 2004 and 2007
- ▶ Declining S-band customer set reduces need for certain NASA antennas



Committed X-Band customers through 2010

- ▶ X-band customer support is relatively steady through 2007+, with requirements through 2010.
- ▶ Long term (2010+) support is uncertain.



Required Support Details:

- Nominal
- Contingency
- Committed
- ▨ Projected
- # Daily Average

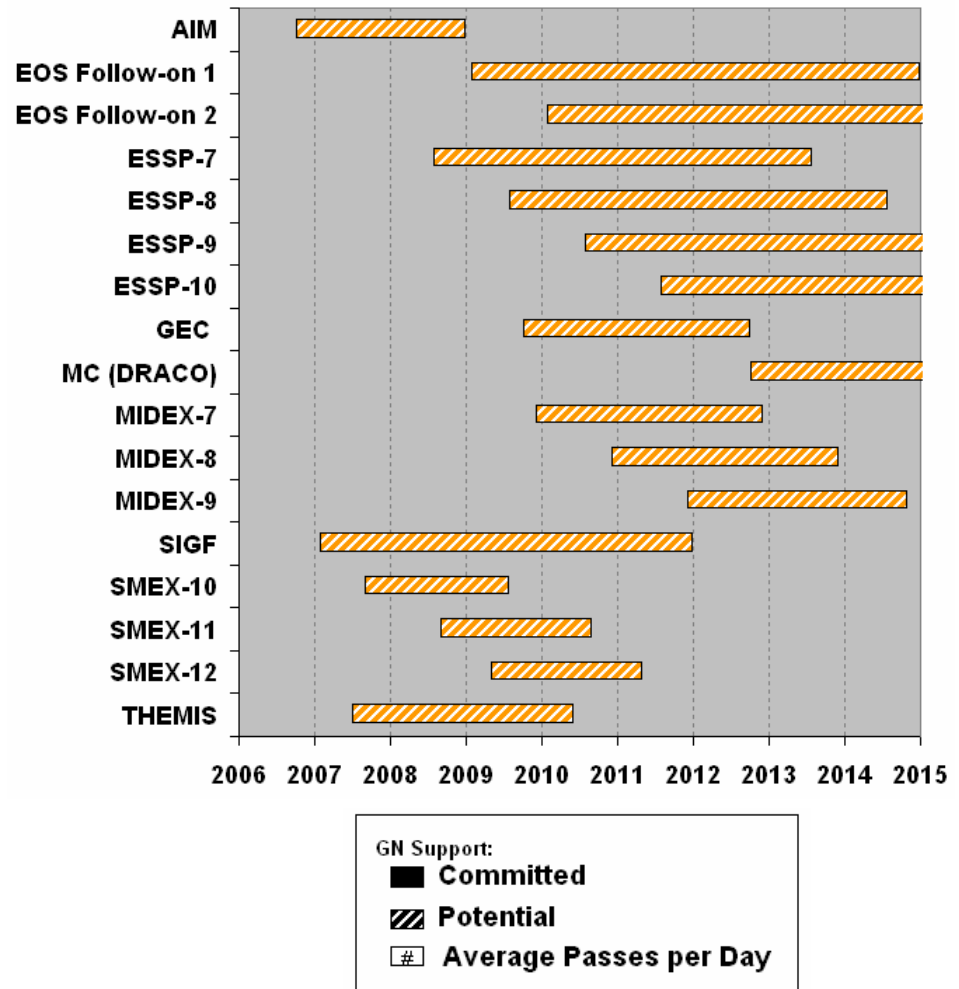
End-of-Mission Constraint:

- Orbit
- \$ Funding
- ▲ On-board Consumables
- ⚙ Radiation Degradation
- ✈ Follow-on Mission
- ✱ Operations Change



Uncertainty in mid- to long- term customer demand

- ▶ Potential customers primarily explorer-class missions (SMEX, MIDEX, ESSP, etc.)
- ▶ Constellation missions (GEC, MC) are also possible GN customers
 - Could require significant GN support
 - Necessitates capacity flexibility
- ▶ Whether these missions use GN depends on cost as well as technical factors



Several significant missions are not planning to use the GN

Mission	Ground Support Requirements				Downlink Frequency	Launch	SCDS Mission Set End of Mission
	GN	SN	DSN	Other			
GPM	C	N			S	Nov-08	Nov-13
LDCM				N	X	Jan-06	Dec-10
NPP		C		N	X	Oct-06	Oct-11
NPOESS (3)		C		N	Ka	Sep-10	Jan-20
OSTM				N	TBD	Dec-06	Dec-11
SDO				N	Ka	Aug-08	Aug-15

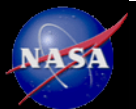
N Nominal
C Contingency Only
L LEOP Only



The GN would like to evolve to a more efficient and flexible architecture

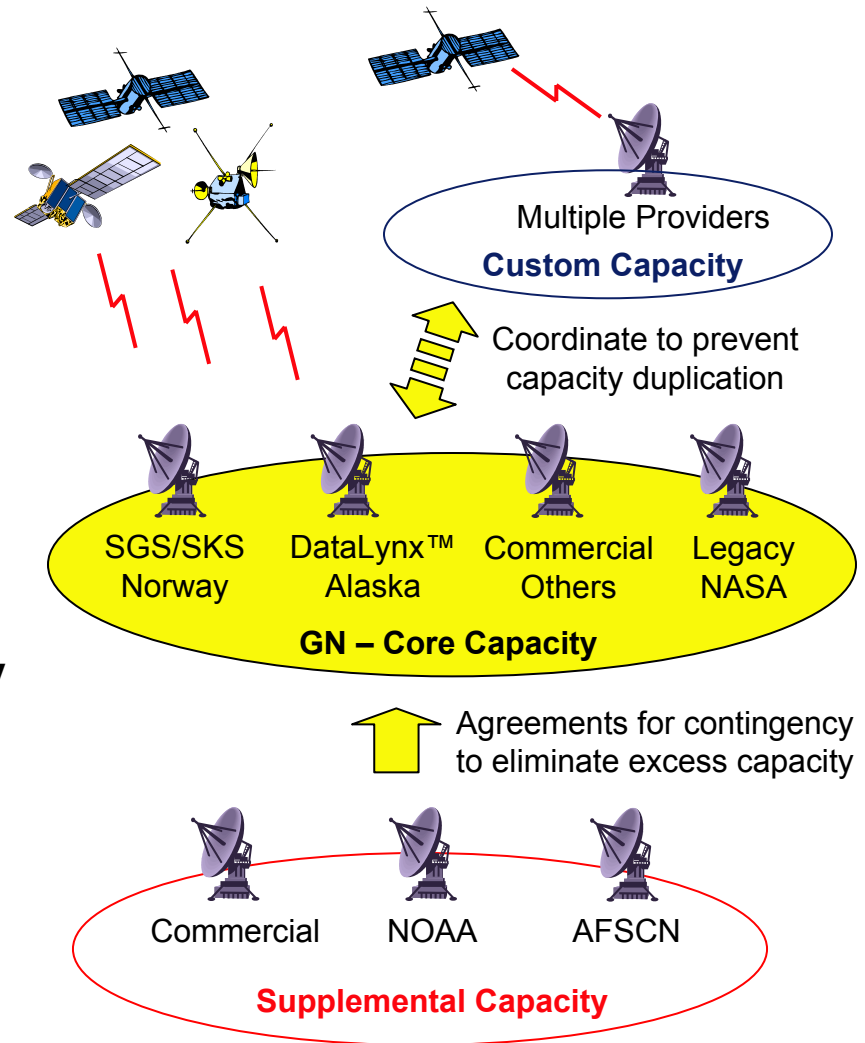
- ▶ Reduce excess capacity
 - Match capacity to changing demand
 - Maintain efficient contingency capacity
- ▶ Reduce aging infrastructure
 - Reduce high costs of operations
 - Reduce maintenance and engineering costs
 - Avoid costly upgrades
- ▶ Develop flexible contingency capacity
- ▶ Increase competitiveness and increase mission customers

Interoperability with other civil space networks may enable greater efficiency and flexibility...



Architecture Vision: Flexible, reliable, and competitive

- ▶ **GN provides core capacity**
 - Multi-mission shared capacity
 - Focus on mission requirements
 - Heavy reliance on commercially owned/operated systems
- ▶ **GN coordinates on custom capacity**
 - Mission-unique capabilities that GN cannot effectively provide
- ▶ **GN diversifies with supplemental capacity**
 - Partner with NOAA, IPO, commercial, etc.
 - Share contingency, launch and early orbit, and backup support



Agenda

- ▶ Overview of the Ground Network
- ▶ Strategic Planning
- ▶ **Interoperability Opportunities**
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Community trends may enable opportunities for coordination

▶ NASA

- Shared support between NASA Space Network and GN will probably increase
- Some overlap in functionality between GN and DSN on Earth-orbit support

▶ NOAA

- Possible X- and S- band contingency capacity
- SafetyNet (NPOESS Ka-band architecture) planned to be operational in 2009

▶ DoD

- Exploring interoperability with other government satellite control systems
- Exploring Transformational Communications for the long term

▶ Commercial

- Some providers maintain business viability in niche markets
- Other providers rely on NASA as their cornerstone customer while they seek to develop a broader market

▶ Partners

- Some NASA missions will continue to receive ground network services from University and International partners



NOAA support of NASA missions might be feasible

- ▶ **NASA GN and NOAA antennas are similar**
 - Key locations at Alaska and Wallops
 - Geographic proximity may enable sharing ground equipment, etc.
 - Similar customer orbits and frequency bands
- ▶ **NOAA support seems feasible, based on preliminary look**
 - Compatibility seems likely to be achievable
 - Availability of NOAA antennas seems reasonable
 - More analysis with NOAA expertise is required
- ▶ **Potential future architectures may also provide opportunities for coordination**
 - NPOESS Ka-band infrastructure

	NASA	NOAA
Locations		
Alaska	✓	✓
Antarctica	✓	
Norway	✓	
Santiago	✓	
Wallops	✓	✓
Customer Orbits		
LEO	✓	✓
LEO Polar	✓	✓
GEO	✓	✓
Antenna Frequency Bands		
S-Band	✓	✓
X-Band	✓	✓
L-Band	✓	✓
UHF	✓	
VHF	✓	✓

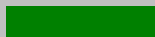
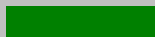
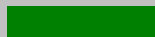
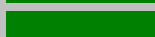
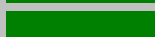
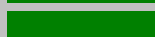












































Supplemental NOAA support of GN customers could reduce NASA risk

- ▶ GN architecture cannot meet some mission requirements in certain ground station contingency situations
- ▶ NOAA contingency support would significantly reduce NASA risks
 - **EOS (Aqua or Aura)** in Alaska
 - **ADEOS-II** at Wallops

	Compatible with NOAA
	Compatibility Unknown
	Not Compatible
<i>na</i>	Not applicable

NOAA Compatibility with NASA Missions

		Aqua	Aura	ADEOS-II
CCSDS Compatible?				
X-Band	Frequency			
	Modulation			
	Polarization			
	Data Format			
	Data Rate			
	G/T			
S-Band (TLM)	Frequency			<i>na</i>
	Modulation			<i>na</i>
	Polarization			<i>na</i>
	Data Format			<i>na</i>
	Data Rate			<i>na</i>
	G/T			<i>na</i>
S-Band (CMD)	Frequency			<i>na</i>
	Modulation			<i>na</i>
	Polarization			<i>na</i>
	Data Format			<i>na</i>
	Data Rate			<i>na</i>
	EIRP			<i>na</i>
Potential Equipment				



Conclusion

- ▶ The GN is a heterogeneous system that supports many diverse customers
- ▶ NASA GN will be evolving its current infrastructure and asset mix
- ▶ As part of its strategic planning, the NASA GN is interested in increasing interoperability between civil space networks
- ▶ Mutual support and inter-agency cooperation could lead to greater efficiencies and reduced risk in the future



Agenda

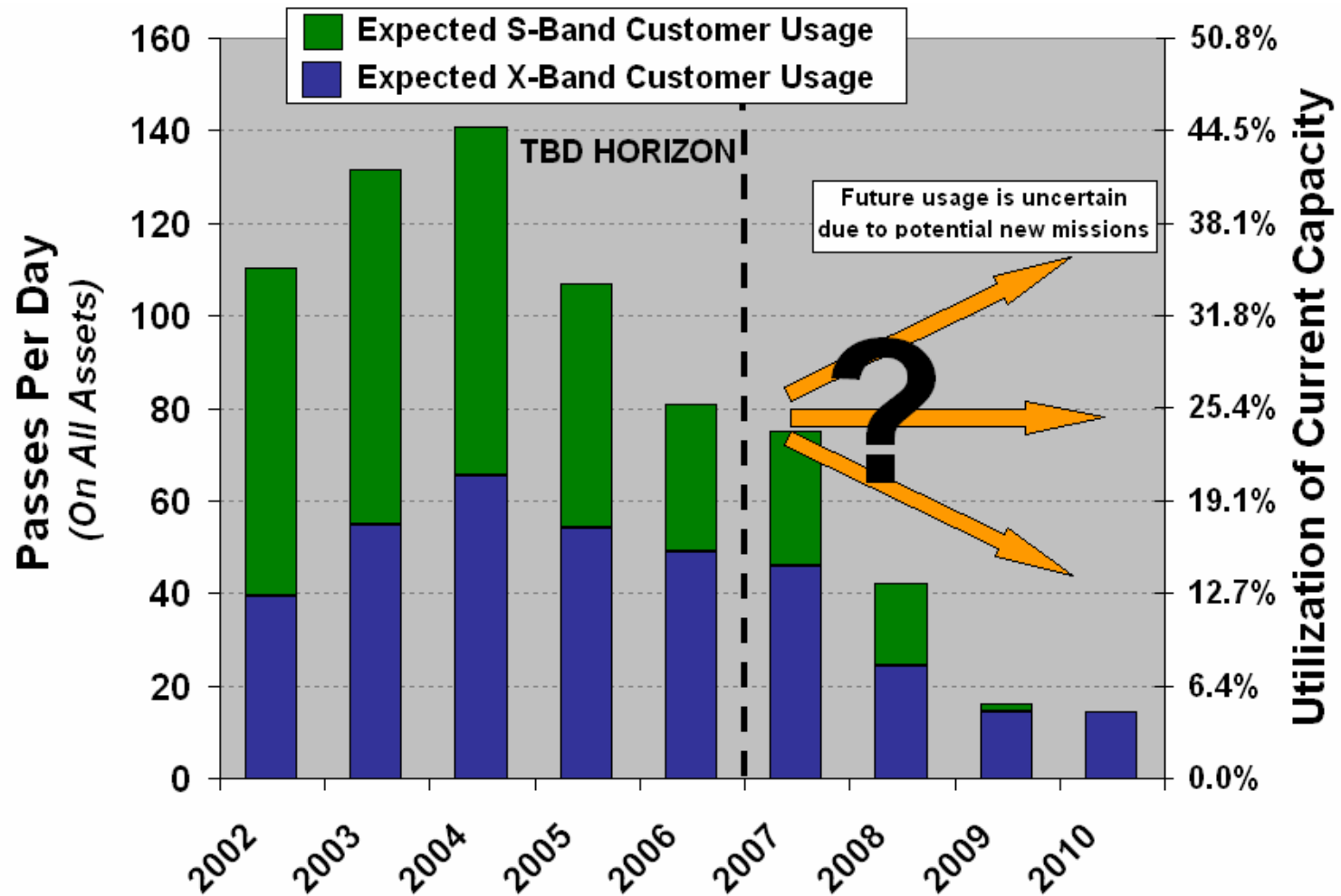
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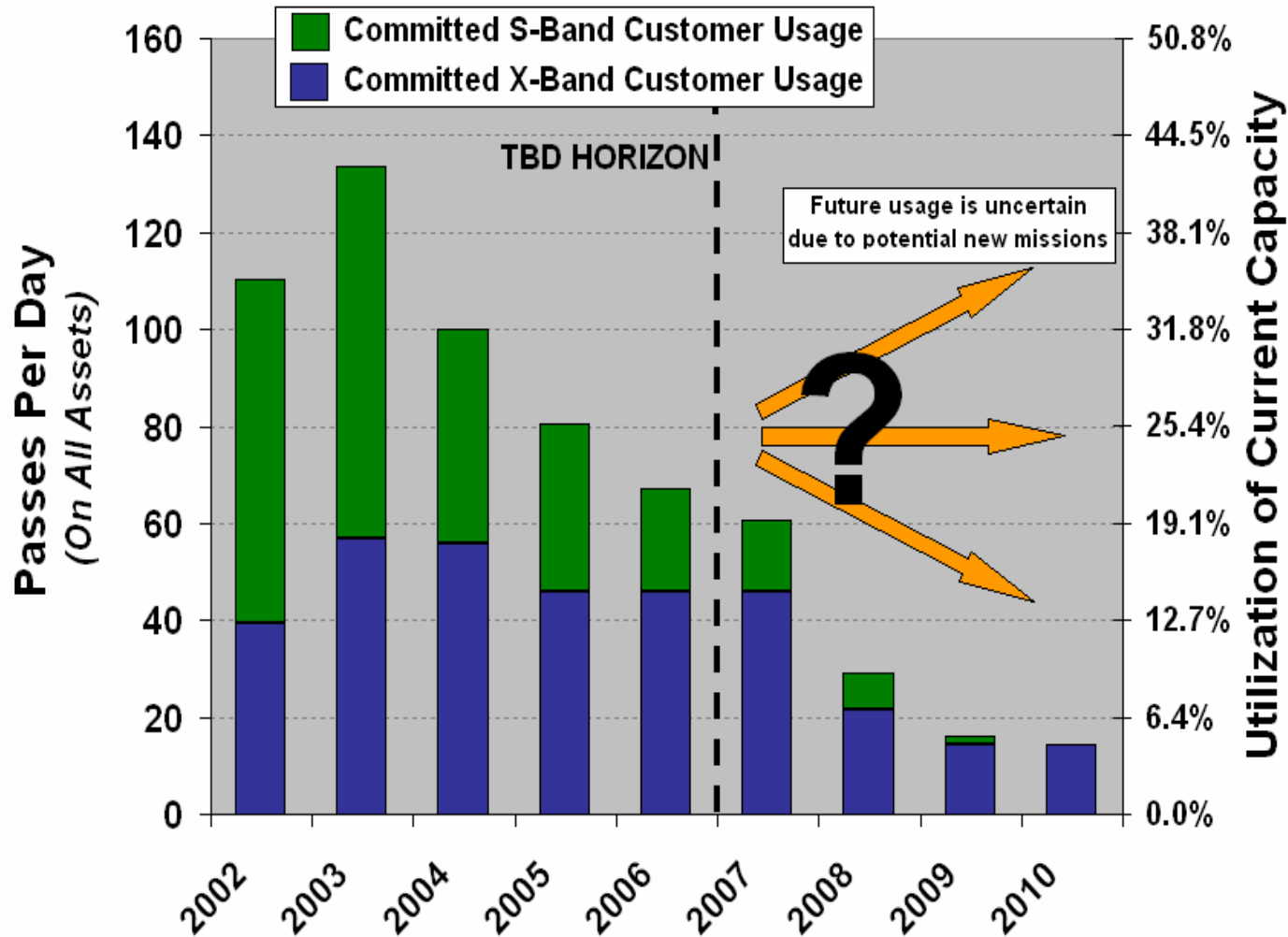
Backup Slides



Expected GN Loading



Committed GN Loading



Detailed compatibility information

		NOAA Assets				NASA Missions											
		VPS 13m	AK 13m	Aqua / Aura		ADEOS-II (X1)		ADEOS-II (X3)		FAST		OrbView-2		TRACE (LR)		TRACE (HR)	
				Carrier	Sub	Carrier	Sub	Carrier	Sub	Carrier	Sub	Carrier	Sub	Carrier	Sub	Carrier	Sub
CCSDS Compatible?		Y	Y	Y		Y		Y		Y		Y		Y		Y	
X-Band	Frequency (MHz)	7250 - 8500	7250 - 8500	8160	na	8150	na	8250	na	na	na	na	na	na	na	na	na
	Modulation	?	SQPSK, ?	SQPSK	na	QPSK	na	QPSK	na	na	na	na	na	na	na	na	na
	Polarization	RCP/LCP	RCP/LCP	RHCP	na	RHCP	na	RHCP	na	na	na	na	na	na	na	na	na
	Data Format	?	?	NRZ-L	na	Modulo-4 Differential Encoding	na	Modulo-4 Differential Encoding	na	na	na	na	na	na	na	na	na
	Data Rate (Mbps)	?	?	150	na	60	na	6	na	na	na	na	na	na	na	na	na
	G/T (dB/K)	36.4	36.4	>35	na	>33.4	na	>33.4	na	na	na	na	na	na	na	na	na
L-Band	Frequency (MHz)	1670-1710	1670-1710	na	na	na	na	na	na	na	na	1702.5	na	na	na	na	na
	Modulation	FM, PM, BPSK, QPSK	FM, PM, BPSK, QPSK	na	na	na	na	na	na	na	na	PM/PSK	na	na	na	na	na
	Polarization	RCP/LCP	RCP/LCP	na	na	na	na	na	na	na	na	RHCP	na	na	na	na	na
	Data Format	?	?	na	na	na	na	na	na	na	na	BiΦ-L	na	na	na	na	na
	Data Rate (kbps)	5000	5000	na	na	na	na	na	na	na	na	665.4	na	na	na	na	na
	G/T (dB/K)	20.3	19.2	na	na	na	na	na	na	na	na	>6.5	na	na	na	na	na
S-Band (dL)	Frequency (MHz)	2200 - 2400	2200 - 2400	2287.5	1024	na	na	na	na	2215	na	2287.5	na	2215	na	2215	na
	Modulation	FM, PM, BPSK, QPSK	FM, PM, BPSK, QPSK	PM	PSK	na	na	na	na	PCM/PM (equiv to BPSK)	na	PCM/PM	na	PCM/PM	na	PCM/PM	na
	Polarization	RCP/LCP	RCP/LCP	LCHP		na	na	na	na	Linear (RHC&LHC)	na	RHCP	na	LCHP	na	LCHP	na
	Data Format	?	?	NRZ-L	NRZ-L	na	na	na	na	NRZ-L or BiΦ	na	NRZ-S	na	NRZ to BiΦ	na	NRZ-L	na
	Data Rate (kbps)	5000	5000	524.288	16.384	na	na	na	na	4.096, 900, 1500, or 2250	na	2000	na	23.4375, 1125	na	1125, 2250	na
	G/T (dB/K)	23.5	23.5	>23		na	na	na	na	>23	na	>12.5	na	?	na	?	na
S-Band (CMD)	Frequency (MHz)	2025 - 2120	2025 - 2120	2106.4	16	na	na	na	na	2039.65	na	2092.59	na	2039.646	16	na	na
	Modulation	PM, BPSK	PM, BPSK	PM	PSK	na	na	na	na	PM	na	BPSK	na	PM	PSK	na	na
	Polarization	RCP/LCP	RCP/LCP	LHCP	na	na	na	na	na	RHCP & LHCP, switchable	na	LHCP	na	LHCP	na	na	na
	Data Format	NRZ-M	NRZ-M	NRZ-L	na	na	na	na	na	NRZ-L	na	NRZ-S	na	NRZ-L	na	na	na
	Data Rate (kbps)	{2}	{2}	2	na	na	na	na	na	2	na	19.2	na	2	na	na	na
	EIRP (dBm)	97.9	97.7	>97	na	na	na	na	na	>89	na	>75	na	>96	na	na	na
	Potential Equipment				Bit Synch Viterbi Decoder Demodulators GSIF, GSIP Doppler Tracking		Bit Synch ADEOS-II Data Stripper SAFS Sony Recorders		Bit Synch Doppler Tracking PTP SAFS		Bit Synch SCD FTP/HP via internet		Soft Decision Bit Synch Doppler Tracking Viterbi Decoder				

Green: Compatible with NOAA

Red: Not Compatible

Orange: Compatibility Unknown

